Statistical, Seismic Stratigraphic, and Facies Analyses and Synthesis of Data and Results from Cruises 331293, 221196, and 221296 on the Western Pacific Margin

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LONG-TERM GOALS

Our research group is collecting and analyzing various levels of high-resolution seismic data and cores, for ground-truthing seismic facies, on continental margins with a spectrum of depositional boundary conditions. The long-term goal of this work is develop stochastic models of variation of geotechnical and seismic property distribution on margins subjected to a spectrum of depositional regimes. The importance of being able to produce these stochastic models is that it provides a means of making predictions (with assignment of statistical risk) of the variation of geotechnical and seismic properties in areas where the only data that may exist for that margin at the time that a prediction is needed is information on physical oceanography or other gross descriptions of depositional conditions on the margin.

OBJECTIVES

- Initially, collect high-resolution seismic data on margins with extreme depositional boundary conditions with objective of subjecting these data to sequence stratigraphic and seismic facies analyses to characterize the magnitude of the impact of variation in depositional regime on seismic stratigraphic architecture and seismic facies distribution.

- Quantify the nature of horizontal and vertical seismic facies heterogeneity within a sequence stratigraphic context, and develop stochastic models of seismic facies heterogeneity produced under depositional conditions described above.

- Assess the impact of the depositional processes from margins with extremely different boundary conditions on the stochastic models of vertical and horizontal distribution of seismic facies (and therefore geotechnical and acoustic properties).

- Determine the minimum data required to predict the distribution of seismic attributes on margins with various depositional boundary conditions by conducting sensitivity tests on survey spacing and associated changes in the distribution of mapped parameters.

- Numerically model sediment transport and deposition associated with storm events on evolving shoreline positions to simulate the stratigraphy that might be produced as a consequence of transgression in a storm dominated shelf environment. Model Results are tested with a chirp sonar and core database.

APPROACH

University of North Carolina Seismic Stratigraphy Group (UNCSSG) is researching the relationships between variations in sedimentary boundary conditions and the stratigraphy produced by these conditions. Limited work has been conducted on relating distribution of near-surface seismic facies and variability in depositional environment boundary conditions. The study area on the Western Pacific Continental Margin (WPCM) is a region with high sediment supply (4 times the amount of sediment per year as the Mississippi River) and large magnitude hydrodynamic sediment transport processes (tidal currents and large waves from typhoons and storms associated with the winter monsoon), so that there may be a high degree of correspondence between the sedimentary processes active on the margin and the preserved stratigraphy. In other words it may be a situation where the sedimentary processes and recent stratigraphy may be in dynamic equilibrium. This situation may be rare today and it may be an "End-Member", but understanding this system is essential to understanding systems where the record of sedimentation is much less complete. In fact this area contrasts quite distinctively with many other continental margins (such as offshore Alabama, offshore Eel River, California, or offshore New Jersey).

UNCSSG is simultaneously conducting an investigation of the 3-D variability of an area (the Alabama Shelf) with low sediment supply, microtidal conditions, and relatively infrequent storm events. Approximately 2,125 km of high-resolution (<1 m) Geopulse reflection seismic data were acquired within a 900 km^2 grid in an area that extends from ≈5 km offshore of the Alabama coast to the upper continental slope. We are developing probability models of the distribution of seismic facies variability in this area and determining the minimum data density required to successfully make predictions of physical property distribution given the set of boundary conditions described above.

The approach for this project is to: (1) acquire data from environments with a history of extreme depositional boundary conditions, (2) conduct sequence stratigraphic analyses of these data to identify units deposited within the same interval of time, and (3) conduct quantitative seismic facies analyses on the data sets so that the variations in seismic facies within each time-slice can be tracked spatially and later subjected to Analysis of Variance, Q-mode factor and binomial markov process analysis to identify non-random variations in seismic facies variability. This provides the stochastic model of spatial variability in acoustic property variability on the continental margin. We then test for sensitivity to survey spacing by under and over sampling isochron maps of seismic facies and thickness of systems tracts at various intervals, overlaying the maps, measuring deviations in orientation of features, and their spatial magnitude and conducting statistical tests to determine when the differences are significant. We are conducting similar analyses when comparing the near-surface sonar facies distributions of the "end-member" continental margins.

We also recently acquired an "Acoustic Core" seismic processing system that we will use on calibrated seismic data to compute variations in velocity, density, impedance, reflectivity, and attenuation with depth. Results of these analyses will be integrated with the results of stochastic analyses of seismic facies so that we can use these investigations to produce models of variation of physical property distribution on continental margins.

We also initiated a collaborative program with the Naval Research Lab in Stennis, Mississippi to numerically model sediment transport and deposition associated with storm events on evolving shoreline positions to simulate the stratigraphy that might be produced as a consequence of

transgression in a storm dominated shelf environment. We are testing model results with a chirp sonar and core database in the East China Sea.

WORK COMPLETED

- Completed stratigraphic and statistical analyses of chirp sonar facies from the initial East China Sea (ECS) data set (which includes 3,428 km of chirp-sonar data) and on 28 sediment cores acquired from the ECS during cruise 331293. A manuscript is being written and will be submitted for publication on process-response relationships among lithofacies, chirp sonar facies, and depositional processes on the inner and middle shelf area of the ECS study area. New chirp sonar data (2,824 km) collected in the WPCM study area during cruise 221196 and 6 new cores collected on cruise 221296 are being integrated into this analysis. Currently thirteen chirp sonar facies are identified and completion of cluster analysis indicates that there are 8 chirp sonar provinces in the study area. Thus far, 6 core provinces are identified in the 34 cores from the ECS margin. One result from analysis of data from the 331293 cruise is that we know that the sediment cores under sample the chirp seismic facies. Both the chirp data and the sediment core data indicate that there are north-south gradients and east-west gradients in the distribution of facies related to proximity to sediment source and distribution of various hydrodynamic forcing mechanisms on the continental margin.

- Completed seismic stratigraphic and facies analysis of 2,825 km of Geopulse high resolution seismic reflection data acquired as part of the initial ECS data set during cruise 331293 and have nearly completed statistical analyses of these results. A manuscript on the results of seismic stratigraphic and facies analysis of Geopulse data from initial ECS data set (331293) was resubmitted to the Geological Society of America Bulletin (GSAB), come back from review, and was revised for publication and resubmitted. Seismic reflection data (2,824 km) collected during cruise 221196 has required a great deal of processing to remove "ringing" from the data and to recover navigation data and this processing was completed mid-October 1998. Seismic stratigraphic analysis of the new seismic reflection data collected during cruise 221196 is complete and being integrated into statistical analyses for the stochastic model of the area. Examination of the new data provides evidence of a stratigraphic architecture in the study area that is not inconsistent with hypothesis presented in the GSAB manuscript. Statistical analyses that are required to complete our stochastic model of the area will be completed shortly and a manuscript will be submitted for publication in a peer-reviewed journal. These analyses will include the additional 2,824 km of high-resolution seismic data acquired during cruise 221196 (total of 5,649 km of high resolution seismic data). To date, we clearly can identify distinctive sequence stratigraphic systems tracts for at least 2 sea level fluctuations on the initial ECS data set. Preliminary comparison to offshore Alabama (GOM) data indicates that the depositional boundary conditions have left a significant impact on seismic stratigraphy and facies distributions in these locales with quite different depositional boundary conditions. However, time constraints during cruise 221196 prevented acquisition of data from the outer continental shelf and upper continental slope in the ECS study area. During our 1999 survey we completed a survey of the outer shelf and slope. So we are ready for detailed comparison to the GOM data set.

- Completed seismic stratigraphic and facies analysis of Geopulse data from offshore Alabama margin and completed statistical analyses of results of this seismic stratigraphic and facies analysis of Geopulse data. A paper on these results has been written and submitted for review and publication in a SEPM Special Publication Volume. We also have made presentations of these results at a number of national level professional conferences. To date we clearly can identify distinctive sequence stratigraphic

systems tracts for at least 2 sea level fluctuations on the Alabama margin and as mentioned above we observe that the near-surface facies distribution is quite different from ECS.

- Completed sensitivity tests on impact of survey profile spacing on successful prediction of property distribution on ECS. Have made 2 presentations of results of these analyses at national level professional conferences and are writing a manuscript on the results for submission to a refereed journal for publication. Next task is to integrate analyses from additional 2,824 km of high resolution seismic reflection data acquired during cruise 221196 and our 1999 survey into existing data set and conduct the sensitivity tests on a data set that is nearly twice as dense.

- Completing sensitivity tests on impact of survey profile spacing on successful prediction of property distribution on Alabama continental margin. This area has very different depositional boundary conditions than those of WPCM and therefore provides a standard to which the ECS results can be compared. We have made 2 presentations of these results at national level professional conferences.

- Initiating comparison of results of stochastic models from margins with extremely different boundary conditions to assess the impact of the processes on development of stratigraphic architecture and distribution of near-surface acoustic and geotechnical properties.

- We have completed processing of approximately 5,024 km of high resolution seismic reflection data collected during cruises 221196 and 221296 in the Yellow Sea and we initiated seismic stratigraphic and facies analyses on high resolution seismic reflection data collected during cruises in the Yellow Sea. Following completion of these analyses we will initiate stochastic modeling of acoustic property distribution in this depositional system. Analyses of relationship of facies distribution with variations in depositional boundary conditions (from published literature) will be conducted on the data as well. We also started sensitivity tests on impact of survey profile spacing on successful prediction of property distribution on this portion of continental margin.

- We are still working on seismic stratigraphic, and facies analyses on approximately 5,024 km of chirp sonar data collected during cruises 221196 and 221296 in the Yellow Sea. Upon completion of these analyses sonar facies will be related to lithofacies and physical properties of cores where possible. Following completion of these analyses we will initiate stochastic modeling of acoustic property distribution in this depositional system. Analyses of relationship of facies distribution with variations in depositional boundary conditions (from published literature) will be conducted on the data as well. We will also start sensitivity tests on impact of survey profile spacing on successful prediction of property distribution on this portion of continental margin. Analyses of variation of sub-surface reflection coefficients, attenuation coefficients, and properties derived from acoustic impedance such as bulk density and velocity of intervals between reflections will be calculated on data that are representative of widely distributed and distinctive sonar facies.

- Completed x-radiography, lithologic description, geotechnical measurements (torvane shear strength tests and measurement of bulk density; sound velocity in cores has already been measured) and grain size analyses of 16 cores collected during cruises 221296 in the Yellow Sea. Results of these analyses of core lithofacies have been related to chirp sonar facies where possible. Have completed stochastic modeling of lithofacies distribution in this depositional system. Analyses of relationship of facies distribution with variations in depositional boundary conditions (from published literature) have been completed on the data as well. A presentation on results of this work was made at a national level meeting.

RESULTS

Our early examinations of the Yellow Sea (YS) data set suggest that the seismic stratigraphy and seismic facies distribution almost appears to be a hybrid of the stratigraphy identified in the GOM and that of the ECS. Highstand units in the YS consist of primarily moderate to high frequency, moderate to high amplitude, sea floor parallel, and very laterally continuous reflections. Transgressive deposit character is determined by proximity to the center of the basin. Significance of these results is that depositional boundary conditions do have an important impact on distribution of acoustic properties of continental margins and we are developing an understanding about how strongly coupled these process-response relationships are and a quantitative perspective on how they vary.

We have completed sensitivity analyses of the data density to identify the positions and morphology of incised valleys of the GOM system. Incised valley structure contour maps require a sample interval of 2.3 km. We also completed the sensitivity analyses on the data density required to characterize heterogeneity in the interfluve environment. We are completing analyses of the heterogeneity within the incised valleys of the GOM system. Initial results suggest that the Incised Valley fill require a sample interval between 2.3 km. to 4.7 km.

Stratigraphy on the WPCM is quite different than stratigraphy developed on continental margins with much lower sedimentation rates and less ability to disperse sediment. Data from the continental margin of the Gulf of Mexico (GOM) consist of highstand deposits of wide lateral extent and relatively homogenous reflection character, lowstand incisions that are narrow (few km to 10 km) and shallow (10's m) and widely dispersed along the margin, and transgressive deposits consisting of thin (1-2 m) sheets of sand or mud.

Our initial results with modeling of storm sedimentation on the WPCM indicates that the 500 year storms with which we are working produce storm beds that are 5 to 20 cm thick and cover areas as large as 90,000 km^2. The model suggests that the storms resuspend sediment but do not produce much lateral advection of the sediment. We are integrating tides and geostrophic flow of thermo-haline currents in the area to study the impact of these on storm sedimentation on the shelf. The resuspension events are capable of eroding down to the preceding storm deposit so the stratigraphy should consist primarily of amalgamated storm beds. We have not yet been able to identify distinctive facies in chirp sonar data or cores that may be associated with storm events.

IMPACT/APPLICATIONS

The scientific impact of this work is that it quantifies relationships between depositional boundary conditions and near-surface seismic/geotechnical properties distribution on continental margins. This therefore leads to more reliable estimates of these properties in areas where it is either difficult to acquire such data, or it is necessary to design a survey that will quickly provide needed insight, with a given level of risk of a bad prediction. It also leads to more successful design of transmission loss surveys and acoustics experiments on the role of bottom interaction on sound propagation in continental shelf environments. This obviously has impact in areas such as oil and gas exploration and production, environmental waste containment, and of course defense related issues on continental margins.

TRANSITIONS

Understanding the process-response relationship between depositional conditions and seismic facies distribution leads to improved understanding of the nature of the heterogeneity of the distribution acoustic properties on a continental margin. The Naval Oceanographic Office has used the results of our analyses to design and conduct more successful transmission loss surveys on the WPCM. They also take data that we provide to them and integrate it into data bases that they provide to the U.S. Navy for operations.

PUBLICATIONS

Refereed Papers:

Bartek, L.R. and Cabote, B.S., Young, T.J. and Schroeder, W., submitted, Sequence Stratigraphy of a Continental Margin Subjected to Low-Energy and Low Sediment Supply Environmental Boundary Conditions: late Pleistocene-Holocene Deposition offshore Alabama, SEPM Special Publication.

Wellner, R., and **Bartek, L.R.,** resubmitted, The Link Between Base Level, Climate, Shelf Physiography and Large Incised Valley Development: A Modern Example from the East China Sea, Geological Society of America Bulletin.

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Lucas, J. L., and **Bartek, L.R. III,** 1999, Minimum Data Density of Northeastern Gulf of Mexico Incised Valleys and Interfluves: Implications for Predicting Nature of Reservoir Heterogeneity, American Association of Petroleum Geologists Annual Conference, San Antonio, Texas, April 11-14, 1999, p. A84.

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